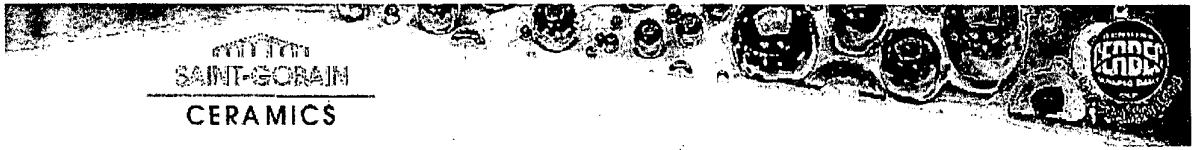

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In this section you can learn about Material Properties:

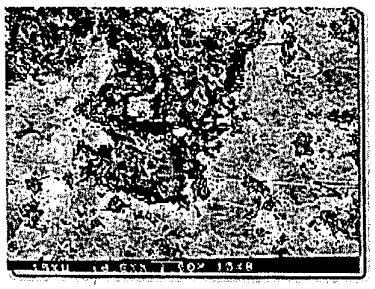
- **Intrinsic Material Properties Are Derived From Atomic Bonding**
- **Bearing Grade Silicon Nitride Requirements**
- **CERBEC Silicon Nitrides For Bearings**

Bearing Grade Silicon Nitride Requirements

For bearings, a silicon nitride must have certain important characteristics to work properly – in other words, not just any silicon nitride will meet the requirements of bearing performance. There are relatively few silicon nitride's on the market that are qualified by bearing companies worldwide. Saint-Gobain makes CERBEC balls from (2) qualified silicon nitrides: NBD-200 and SN-101C which are described below.

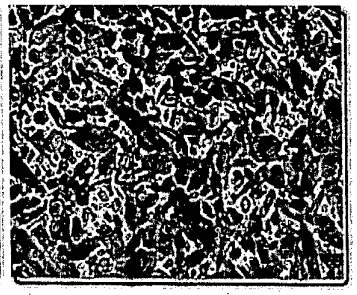
Intrinsically, silicon nitride's crystal lattice structure is predominantly all covalently bonded with very strong, directional bonds in a diamond-like atomic packing arrangement. Like most ceramics, however, silicon nitride cannot be practically fabricated into "single crystal" components. Instead, silicon nitride grains must be bonded together into a "poly-crystalline" material with micron-sized, needle-like, silicon nitride grains (each a small, single crystal), held together by a secondary glassy phase which is necessary for sintering densification of a component (see photo of microstructure pointing out silicon nitride & glass phases). Silicon Nitride grains exist in (2) main crystalline "polymorphs" – alpha and beta. The key to engineering bearing grade silicon nitride properties is controlling the alpha to beta transformation during densification as well as selecting the volume % of glass phase used. The "beta" polymorph is characterized by "acicularity" or needle-like shape which gives silicon nitride bearing components their toughness, strength, and rolling contact fatigue resistance. Silicon Nitride densification can only be accomplished via "Liquid Phase Sintering" by a "Solution/Re-precipitation" phenomena which requires that an inter-granular glass be formed for the alpha silicon nitride to dissolve into and for the beta silicon nitride to precipitate out from. The liquid phase is required for "material transport" during the densification process.

Typically speaking, the "more" liquid phase you have the lower the temperature and pressure required for densification and microstructural development. But, the "more" liquid phase you have, the more difficult it is to gain the appropriate properties for "bearing grade" silicon nitride. Typically,bearing grade silicon nitrides possess relatively low amounts of liquid phase (>15 volume %) and need to be densified at very high temperatures and pressures to provide the necessary kinetic and thermodynamic driving force to promote the proper alpha to beta transformation.



NBD200 Microstructure (10,000X Glass Phase Etched Out)

SN101C Microstructure (10,000X Glass Phase Etched Out)



SN101C Microstructure (10,000X Without Glass Etched Out)

The best bearing grade silicon nitrides have certain attributes in common in order to possess the appropriate level of hardness, toughness, crack resistance, strength, processability, and rolling contact fatigue life including:

a. Nearly 100% density or very, very minimal content of very small pores (<5 micron maximum)
b. Micron sized grain structures of acicular, needle-like beta grains; >85% beta phase typical
c. Moderate to low amounts of glass phase (<10 volume % typical)
d. Processed using Hot Isostatic Pressing (HIP) at very high temperatures and pressures to assure very high density and product uniformity

CERBEC silicon nitrides meet all these requirements routinely.

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